Experimental Investigation on Steel Fiber Reinforced High Strength Concrete Mix

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ABSTRACT: *The objective of present research work is to investigate experimentally mechanical behavior of steel fiber reinforced concrete (SFRC). In this the compressive and flexural strength of steel fiber reinforced concrete has studied for High Strength Concrete mix with different volume fraction of steel fibers. And compare the strength with plain high strength concrete to know the volume of steel fiber which has maximum effect on mechanical properties improvement.*

Keywords: *Steel fibres, High strength concrete, Compressive strength, Flexural strength.*

1. INTRODUCTION:

According to ACI committee High strength concrete is generally defined as concrete with compressive strength greater than 6000psi or 42 MPa. The methods for producing High strength concrete (HSC)is not substantially different when compared with methods which produce normal concrete. The water/cement ratio should be in the range of 0.3 to 0.35 or even low. Super plasticizer with their optimum dosages is used to achieve maximum amount of water reduction. High strength concrete has various advantages over normal concrete. High strength concrete made it possible to build higher and longer span structures. Use of High strength concrete results reduction of compression member sizes which proves HSC is an attractive profit from engineering characteristics. But the higher compressive strength of HSC welcomes brittleness pronouncedly. In this present study a concrete mix design is made for High Strength Concrete of M50 Grade as per ACI and steel fibers are added in terms of % of volume fraction of concrete. The amount of percentages varies from 0.5% to 3% at an interval of 0.5%.New fibre percentages are introduced by Kishore et.al (3), and Suresh et. al (10). Thefresh concrete tests like slump cone test and vee bee consistometer test and as well as hardened concrete tests like compressive strength, flexural strength at the ages of 7, 28 days were conducted. By comparing these experimental results with plain concrete, the influence of fibers on compressive and flexural strengths of High Strength Concrete has been studied.

2. METHODOLOGY:

The experimental investigation consists of casting and testing of different concrete mix sets along with control mix. Each set consists of 3 cubes, 3 prisms for determining compressive and flexural strengths respectively. Mechanical properties testing for both 7 days and 28 days have been carried out. Steel fibers are incorporated in the study with different percentages of volume fractions (0.5%, 1%, 1.5%, 2%, 2.5%, 3%) of fibers.

The experimental work is carried out into two phases. First phase of work is development of high strength concrete mix using chemical admixture and second phase is improving the mechanical properties of high strength concrete using fibers.

Cube specimen dimension is of 15 cm x 15 cm x15 cm, prism specimen dimension is 50 cm x 10 cm x 10 cm. The moulds are applied with a lubricant before placing the concrete. After a day of casting the moulds are removed and cubes and prisms are moved in to curing tank carefully.

The material characteristics that are used in this work given brief are as follows

- Ordinary Portland cement 53 grade with specific gravity of 3.15.
- Locally available river sand with bulk density of 1705 kg/m^3 and specific gravity of 2.64 and confirming to zone-II of IS: 383 – 1980.
- Coarse aggregate with bulk density of 1675 kg/m^3 and specific gravity of 2.81.
- Water conforming to the requirements for concreting and curing as per IS: 456—2000.
- Steel fibers: Mild Steel Hooked end HKL 65/35(length–35 mm and diameter – 0.55 mm).

2.1 Steel Fibers

Steel fibers can be produced in different shapes, in which deformations may extend through the length of the fiber or may be limited to the end portions. Depending on the type of steel and the type of production technique, steel fibers may have tensile strengths of about 280-2800 MPa and ultimate elongations of about 0.5% to 3.5%.

Type	Mild Steel Hooked End Fiber
Length	35 mm
Diameter	0.55 mm
Aspect ratio (l/d)	65
Tensile strength	> 1100 MPa
Conforms to	EN 14889 –1, ASTM A820 M04 Standards

Table.1 Specifications of Steel Fibers used in the present study

Fig.1used Hooked end steel fibers in the study

Mix design carried out by using **ACI:211.4R –93** (Reapproved 1998)method. The mix proportion obtained for plain **M50**grade concrete is **1:1.41:2.56:0.007(SP)** with water – cement ratio **0.32.**

2.2 Workability:

Workability of concrete is represented as the ease and homogeneity of fresh concrete for mixing, placing and compaction. In this study addition of different percentages of volume of steel fibers makes the high strength concrete mix stiff. Due to this Vee – Bee consistometer test is used which is most suitable for stiff concrete and low workability mixes.

Vee – Bee consistometer test is carried out for different steel fiber mixes in concrete to determine the workability as per IS 10510: 1983.

% of fiber	Workability(Vee-bee seconds)
0%	3
0.5%	7
1%	10
1.5%	14
2%	22
2.5%	31
3%	48

Table. 2 workability of concrete for different percentages of steel fiber (Vee – Bee test)

2.3 Compressive strength

The cubes are generally tested for 7 days and 28 days. The cubes are tested using calibrated compression machine. The cubical specimens are placed on compression testing machine having a capacity of 2000 KN. The cubes are tested on the face perpendicular to the casting

face. So the cubical specimens should be placed in such a manner that the load shall be applied to the sides of the specimen that is not to top or bottom. A uniform rate of loading 140 kg/sq.cm/min is maintained. Maximum load at which the cubical specimen fails is noted. The compressive strength is calculated using following formulae

$$\text{Compressive strength} = \frac{maximum\ \ load\ at\ failure}{area\ of\ specimen}$$

$$= P/A$$

2.4 Flexural strength

Usually flexural strength test carried out for 28 days. After 28 days curing, prism specimens are placed on machine having capacity of 100 KN by placing the specimen in such a way that the two-point loading should be placed at a distance of 13.3 cm from both ends. Ultimate load ate which the prismatic specimen fails is noted. If ‘a’ is the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of specimen then the flexural strength can be calculated using the formula

Flexural strength= $\frac{PL}{BD^2}$

When "a" is greater than 20.0 cm for 15 cm specimen or greater than 13.3 cm for 10 cm specimen

Flexural strength= $\frac{3Pa}{BD^2}$

When "a" is less than 20.0cm but greater than 17.0cm for 15 cm specimen or less than 13.3 cm but greater than 11.0 cm for 10 cm specimen.

3. RESULTS AND DISCUSSIONS

3.1 Experimental Results

S.NO	%OF FIBERS	7 DAYS COMPRESSIVE STRENGTH (MPa)	28DAYS COMPESSIVE STRENGTH (MPa)	FLEXURAL STRENGTH (MPa)
1	0%	38.29	60.7	7.183
2	0.5%	40.7	64.1	9.1
3	1%	42.11	65.86	11.373
4	1.5%	44.17	68.72	12.15
5	2%	45.3	70.12	12.78
6	2.5%	43.4	68.3	13.029
7	3%	41.2	66.64	12.42

Table.3Test results of mechanical properties of HSC with addition of steel fiber

S.NO	%OF FIBERS	7DAYS COMPRESSIVE STRENGTH MPa	%OF INCREASE
1	0%	38.29	0
2	0.5%	40.7	6.29
3	1%	42.11	9.97
4	1.5%	44.17	15.35
5	2%	45.3	18.30
6	2.5%	43.4	13.30
7	3%	41.2	7.60

Table.4Effect of steel fibers on 7 days compressive strength of M 50 Grade concrete

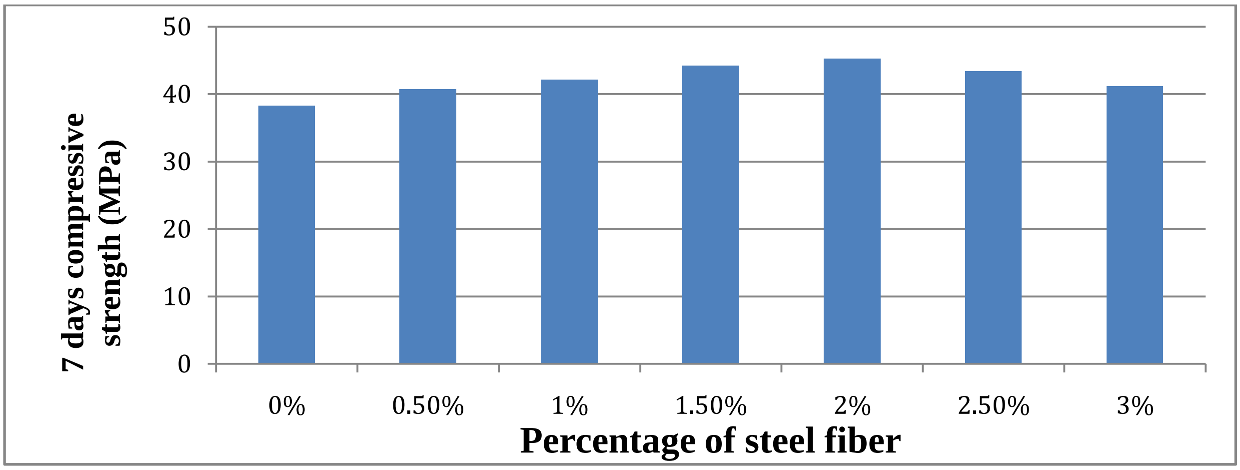

Fig 2: graph showing variation of 7 days
Compressive strength of concrete at different % of volume fraction (V_f) of steel fibers.

(i) From above graph it is observed that the 7 days compressive strength is higher at 2% of steel fibers

when compared with other % of $V_f$of steel fibers. The value of 7 days compressive strength for M 50 Grade at 2% is found to be 45.3 MPa.
(ii) The 7 days compressive strength has been increased by 6.29% to 18.3% for fiber volumes of 0.5% to 2%.
(iii) The percentage increase in 7 days cube compressive strength for mix with 2% of steel fibers is found to be 18.3%.
(iv) From 2.5% of V_f the compressive strength of cubes has been decreased.

S.NO	%OF FIBERS	28DAYS COMPRESSIVE STRENGTH MPa	%OF INCREASE
1	0%	60.7	0
2	0.5%	64.1	5.68
3	1%	65.86	8.50
4	1.5%	68.72	13.20
5	2%	70.12	15.51
6	2.5%	68.3	12.52
7	3%	66.64	9.78

Table.5 Effect of steel fibers on 28 days compressive strength of M 50 Grade concrete.

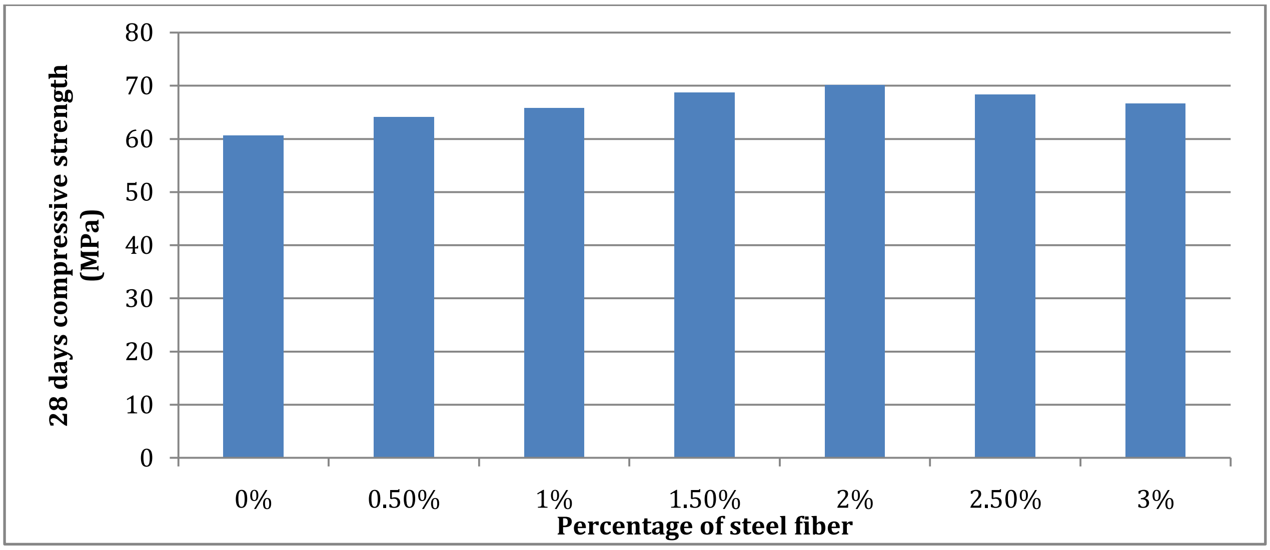

Fig 3 Graph showing variation of 28 days compressive strength of concrete at different % of volume fraction (V_f) of steel fibers.

(i) From above graph it is observed that the 28 days compressive strength is higher at 2% of steel fibers when compared with other % of $V_f$of steel fibers. The value of 28 days compressive strength for M 50 Grade at 2% is found to be 70.12 MPa.
(ii) The 28 days compressive strength has been increased by 5.68% to 15.51% for fiber volumes of 0.5% to 2%.
(iii) The percentage increase in 28 days cube compressive strength for mix with 2% of steel fibers is found to be 15.51%.
(iv) From 2.5% of V_f the compressive strength of cubes has been decreased.

S.NO	%OF FIBERS	FLEXURAL STRENGTH MPa	%OF INCREASE
1	0%	7.183	0
2	0.5%	9.1	26.68
3	1%	11.373	58.33
4	1.5%	12.15	69
5	2%	12.78	77.90
6	2.5%	13.029	81.40
7	3%	12.42	74.30

Table.6 Effect of steel fibers on flexural strength of M 50 Grade concrete.

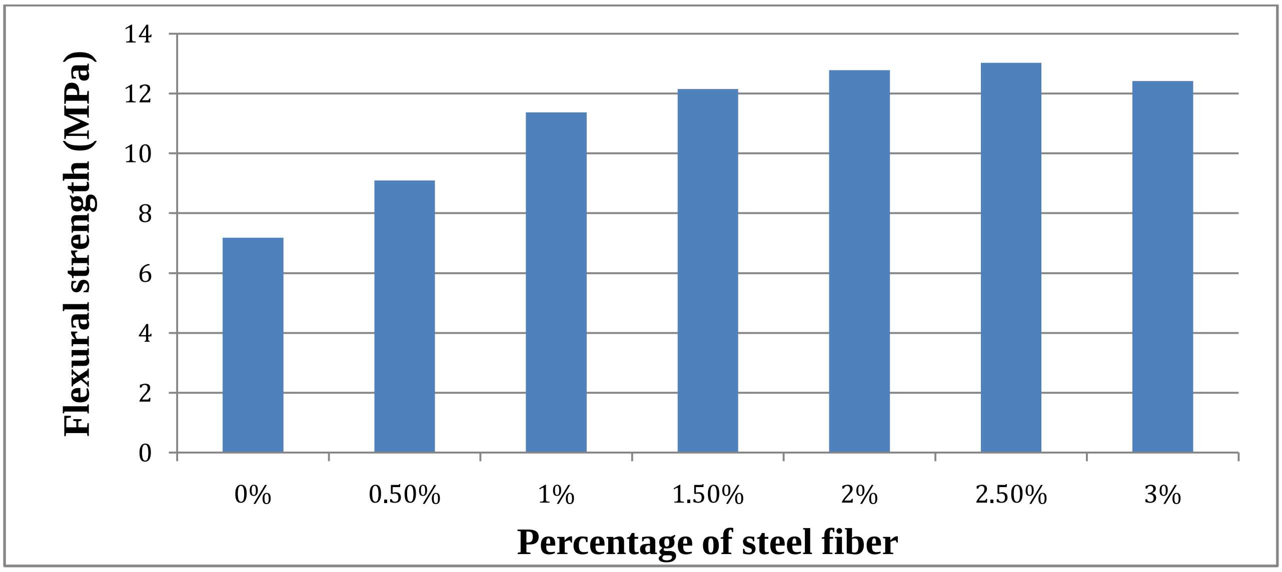

Fig 4 Graph showing variation of flexural strength of concrete at different % of volume fraction (V_f) of steel fibers.

(i) From above graph it is observed that the flexural strength is higher at 2.5% of steel fibers when compared with other % of $V_f$of steel fibers. The value of flexural strength for M 50 Grade at 2.5% is found to be 13.029 MPa.

(ii) The flexural strength has been increased by 26.68% to 81.40% for fiber volumes of 0.5% to 2.5%.

(iii) The percentage increase in flexural strength for mix with 2.5% of steel fibers is found to be 81.4%

(iv) From 3% of V_f flexural strength of concrete has been decreased.

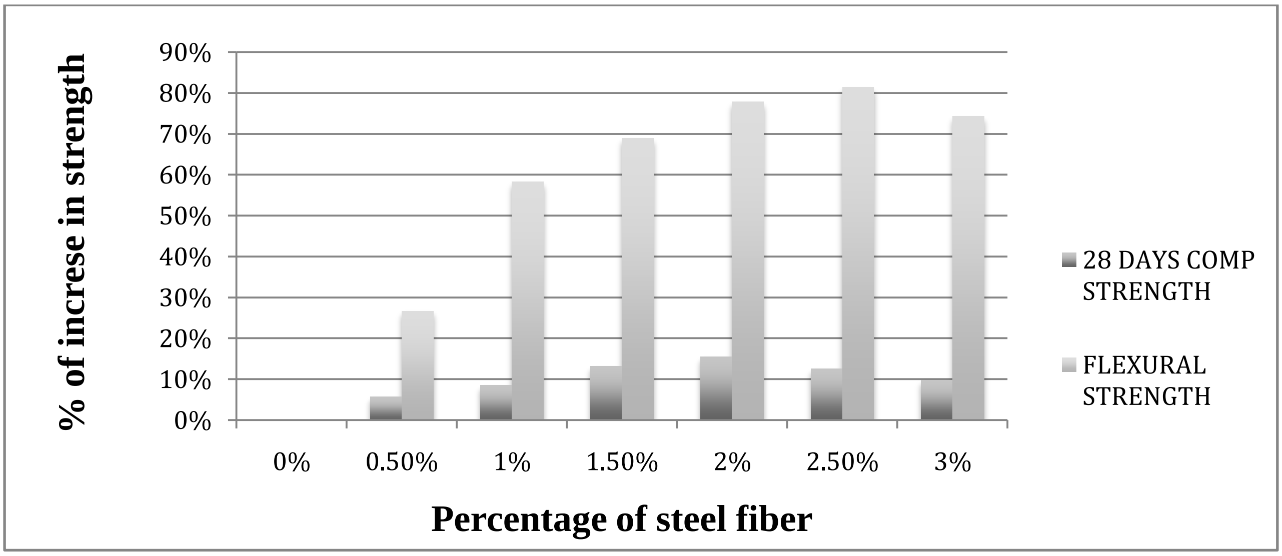

Fig 5 Graph showing comparison of % of increase in compressive and flexural strength of concrete at different % of volume fraction (V_f) of steel fibers.

(i) In SFRC increase in compressive strength is mainly due to the bonding between concrete matrix and steel fibers. When load is applied the steel fiber orientation resists the propagation of cracks after initial cracking up to certain extent which increases the load carrying capacity.
(ii) Whereas SFRC specimen under loading exhibits post – peak behavior. This post – peak behavior improves the ductility and delays the crack propagation which results increase in flexural strength.
(iii) From above graph it is observed that the addition of fibers has more significant effect on flexural strength of the concrete whereas addition of steel fibers has less significant effect on compressive strength.
(iv) There is reduction of compressive strength from 2.5% of steel fiber volume and reduction of flexural strength from 3% of steel fiber.

%of steel fiber	Workability (Vee-bee seconds)	Property of concrete mix
0%	3	Plastic
0.5%	7	Stiff
1%	10	Stiff
1.5%	14	Very stiff
2%	22	Dry
2.5%	31	Extremely dry
3%	48	Harsh mix

Table.7 Property of concrete mix for different % of steel fiber based on workability

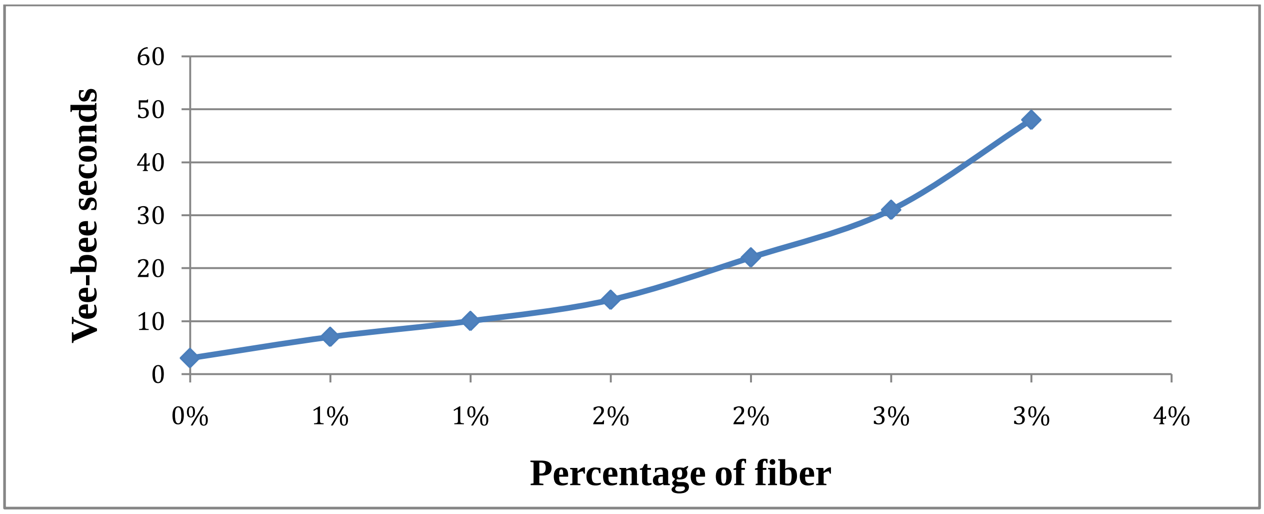

Figure. 6Graph showing variation of workability with different % of steel fiber volume in SFRC

(i) From above graph it is observed that the addition of steel fibers decreases the workability of concrete mix.
(ii) Addition of higher volume of fibers to concrete reduces the workability to an extent even addition of admixture cannot improve the condition, low workability leads to harsh mix which is the reason for reduction of strength characteristics.
(iii) The strengths have been increased up to certain extent of fiber volumes at which the reduction of strengths for higher fiber volume mixes due to lack of workability.
(iv) Harsh mixes do not have proper bonding in concrete which causes separation of materials while compacting. The separation of steel fibers in the concrete mix is represented as bailing effect which is the main reason to reduction of stiffness of concrete – fiber matrix leading to the reduction of strength.

CONCLUSIONS

Based on the Experimental investigation conducted on the casted cubes, prisms, the following conclusions were drawn.

- Concrete with 2% of volume of steel fibers when compared with other percentages showed an increase in 7 days and 28 days of compressive strengths by 18.3%, and 15.51% respectively.
- Concrete mix with 2.5% of volume of steel fibers showed an increase in flexural strength of 81.4% when compared with other percentages.
- The incorporation of steel fibers in high strength mix has significantly improved flexural strength over compressive strength.
- Improvement of compressive and flexural strength has been limited to 2%, and 2.5% of steel fiber volume respectively.
- Higher percentage of volume of steel fiber incorporation in concrete results extremely dry mixes because of low workability.
- Low workability mixes show less bonding between steel fiber and concrete matrix which creates bailing effect of steel fiber results decrease in strengths at higher volumes of steel fibers.

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